

Temperature dependence of the chemical potential in Bi2212.

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Introduction

Recently, the doping dependence of the chemical potential in various kinds of cuprates has been studied using X-ray photoemission spectroscopy (XPS) [1,2,3]. These studies have implied differences in the electronic structure near the chemical potential between different families of cuprates. Namely, it has been suggested that the different doping dependence of the chemical potential arise from whether in-gap states are created by doping or not, or from the differences in the next-nearest-neighbor hopping parameter t' [4]. However, those measurements were performed at a fixed temperature and important information from the temperature dependence of the chemical potential has been missing. Since the surface of $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+\delta}$ (Bi2212) is believed to be more stable than the other cuprates, Bi2212 is the most suitable system among the high- T_c cuprates to measure the temperature dependence of the spectra. There were few reports about the temperature dependence of the valence band spectra in Bi2212 and no clear information has been obtained so far.

In the present work, we have performed the systematic studies of angle-resolved photoemission spectroscopy (ARPES) measurements on optimally doped Bi2212 in a wide temperature range and estimated the chemical potential shift from the shift of the valence band.

Experimental

ARPES measurements were carried out at beamline 28A of Photon Factory (PF). Incident photons had an energy of $h\nu = 55$ eV and 68 eV. A SCIENTA SES-2002 analyzer was used in the angle mode with the total energy and momentum resolution of ~ 20 meV and $\sim 0.3^\circ$, respectively. Samples were cleaved *in situ* at 10 K under an ultrahigh vacuum of 10^{11} Torr, and measured from 10 K to 280 K. The position of the Fermi level was calibrated with gold spectra with the accuracy of < 1 meV. Single crystals of $\text{Bi}_2\text{Sr}_2\text{Y}_{0.08}\text{Ca}_{0.92}\text{Cu}_2\text{O}_{8+\delta}$ were grown by the traveling solvent floating-zone (TFTZ) method. The T_c of this sample was 95.5 K.

Result and Discussion

Figure 1(a) shows the temperature dependence of the energy distribution curves (EDC's) at (π, π) . It is clear that the $\text{Cu } 3d_{3z-r^2}$ band ~ 1.5 eV below E_F is shifted toward higher binding energy with increasing temperature.

Figure 1(b) shows the temperature dependence of the energy shifts of the $\text{Cu } 3d_{3z-r^2}$ spectra relative to the

energy position at low temperature (10 K) compared with the results of the previous core-level photoemission [5]. We used the peak position to estimate the energy shifts of the $\text{Cu } 3d_{3z-r^2}$ spectra. According to the previous study, main contribution of the binding energy shift of each core level and the valence band is the chemical potential shift [1,2,3,6]. Therefore, the energy shift of the $\text{Cu } 3d_{3z-r^2}$ spectra reflects the chemical potential shift. Temperature dependence of the chemical potential predicted by $t-t'-J$ model calculation is also plotted in FIG. 1(b) [4]. The chemical potential shift estimated from the valence-band shift showed temperature dependence similar to that estimated from the core-level shift. According to the $t-J$ model calculation, i.e., with $t' = 0$ [7], it is predicted that the chemical potential shows almost no shift with temperature at optimal doping, which does not explain the present results. However, the observed temperature dependence of the chemical potential shows similar shift to that expected from the $t-t'-J$ model calculation. This suggests that t' is important to explain the temperature-dependent chemical potential shift.

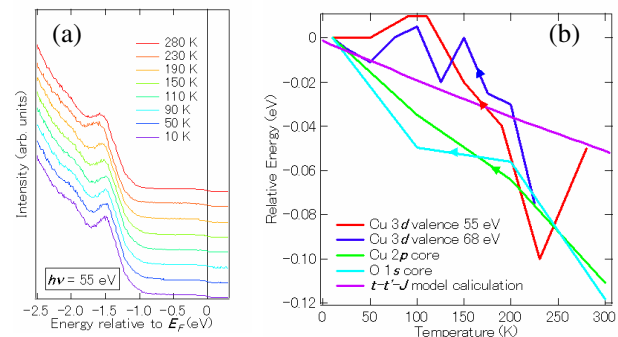


FIG. 1: Temperature dependence of the spectra of the $\text{Cu } 3d_{3z-r^2}$ band. (a) EDC's at (π, π) . (b) Energy shifts of the $\text{Cu } 3d_{3z-r^2}$ band relative to 10 K.

References

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